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this element can affect water powerfully is shown from the circumstance that its sulphate crystallizes with seven molecules of water of crystallization.

The values of A are not, except in the cases of hydrochloric acid, magnesium sulphate, and of sulphuric acid, already cited, the same as the heat capacities of the molecules of the solute, but are larger than they are. It is hard to account for this as we did in the corresponding case of the increased heat capacity of the non-electrolytes when they were in solution, by supposing an increase in their own degrees of freedom. We are led rather to suppose that the molecule of solute affects the surrounding water so as to increase its heat capacity. On the assumption that the number of water molecules affected is 8, except in the case of the two compounds containing potassium, and that for them the number is 14, we get in general the value 3 for the change in the heat capacity of each water molecule affected, or an increase of one sixth its heat capacity.

Of course such statements as these are merely suggestions. I hope that in time the specific heats of electrolytic solutions will be so accurately known as to make it possible to feel certain whether or not a law really obtains in the values of the constants of the formula.

Considering the bearing of the relations that have been adduced upon the general question of the equipartition of energy, it seems to me that their general consistency with that principle, especially the way in which the heat capacities of the organic compounds can be portioned out among the atoms by means of simple assumptions about their degrees of freedom, does afford some confirmation of the principle. Mere chance can hardly account for so large a number of successful coincidences.

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TRANSPORTATION AND COMBINATION.¹

WE are so constituted that each of us looks at the problems of life from a somewhat different standpoint. The opinions we form, the principles we uphold, the policies we advocate, are all influenced more or less by the work in which we engage and the kindred range of our reflections. It is natural, therefore, that I should find the origin of many present-day questions in the facts of modern transportation and communication, and that I should entertain views, perhaps indulge in fancies, which those facts suggest.

The primitive man traveled on foot and moved his scanty belongings by carrying them in his arms or on his back. Even the rude vehicles and water-craft which he eventually learned to construct were propelled by his own muscle, and we can only guess how long it was before he obtained any other motive power for the transfer of his person or his property. In every way his life was meager and isolated, for he had not acquired the art of writing, and intercourse with his fellows was confined to ordinary speech. Outside the family to which he belonged, or the tribe with which he gathered, he had no community of interest, felt no friendship and desired no alliance. His associations were as limited as his means of conveyance.

In a later but still very remote period there came a great increase of motive power by the subjugation of animals, and their employment for transportation on land, and by the use of sails and rudders which multiplied many times the efficiency of water carriage. When these two results were secured, man had added to his own bodily powers the superior strength of beasts of burden and the enormous energy

¹ Address of the vice-president and chairman of Section I—Social and Economic Science, American Association for the Advancement of Science, New Orleans, 1905.

derived from the winds of heaven. This was an immense advance and marked the beginning of that wonderful civilization which slowly followed. The animal kingdom was brought into service for the various functions of land distribution, and the ship which could be sailed and guided made every waterway subservient to man's requirements. Early in this period also he learned to express his ideas by symbols or written words, and thus was enabled to transmit his thoughts by the same agencies that transported his possessions.

This leads to a fact of history which seems to me not merely significant, but profoundly impressive. With the subjection of animals and the use of wind-propelled vessels, both of which achievements reached a high degree of perfection in the unknown past, the means of transportation, broadly speaking, remained unchanged and unaugmented until almost down to the present time. Long before other agencies of conveyance were dreamed of, while ox and horse, oar and sail, were the only means of transport, the race had occupied most of the habitable globe and reached high levels of national greatness. Strong governments were established, vast populations engaged in varied pursuits, and opulent cities crowded with every luxury. The institutions of society had acquired strength and permanence, the arts of leisure and refinement had approached the limits of perfection, and inductive science had laid firm grasp on the secrets of nature. Great inventions and discoveries had widened the fields of activity, furnished the means and incentive for multiplied vocations, and opened up in every direction alluring vistas of advancement. In a word, there was the developed and splendid civilization of only little more than threescore years ago, before any new or different motive power was utilized for production or distribution.

To my mind it is a matter of fascinating

import that the long procession of progress down to the century just ended was conditioned by and dependent upon agencies of transportation which were themselves essentially unprogressive and incapable of important betterment. True, there were minor modifications from time to time in the line of mechanical adjustment, but the general methods employed, and the results obtained, showed no marked improvement or material alteration from those applied in the earliest days of commerce. Reduced to the forms in ordinary use, there were at the last as at the first the beast of burden on land and the oar and sail on water. Yet thus hampered and restricted in the means of transportation, which is the basis of all development, there was built up in the long process of years the varied and advanced civilization which the last century inherited.

Then all at once, as it were, into and through this social and industrial structure, so highly organized, so complex in character, so vast in its ramifications, yet so adjusted and adapted to the fixed limitations of animal power, was thrust the new mode of conveyance by mechanical force, the sudden wonder of transportation by steam. The advent of this new and marvelous agency was the greatest and most transforming event in the history of mankind. It wrought an immediate and radical change in the elemental need of society, the means of distribution. The primary function was altered both in essence and in relations. The conditions of commercial intercourse were abruptly and fundamentally altered, and a veritable new world of energy and opportunity invited the conquest of the race.

No other triumph over the forces of nature compares with this in its influence upon human environment. It has directly and powerfully affected the direction and volume of commercial currents, the location

and movements of population, the occupations and pursuits in which the masses of men are engaged, the division of labor, the conditions under which wealth is accumulated, the social and industrial habits of the world, all the surroundings and characteristics of the associated life of to-day. The world has seen no change so sudden and so amazing.

The next fact to be noted is hardly less remarkable. Not only are the new methods of transportation incomparably superior in speed, cheapness and capacity, but, unlike those which have been supplanted, these new methods are themselves capable of indefinite increase and expansion. The maximum efficiency of an animal is so well known as to amount to a constant quantity, and this unit of power is virtually unchangeable. Substantially the same thing is true of a vessel of given dimensions and given spread of canvas. For this reason distribution remained, as I have said, the one fixed and inflexible element to which all other activities, however elastic and progressive, were necessarily adjusted and by which they were limited.

Now, a special and most suggestive feature of transportation by steam, electricity and other kinds of mechanical force is that its capacity is not only unmeasured and unknown, but will doubtless prove to be practically inexhaustible. That is to say, no certain limits can be assigned to the operation or effect of these new agencies as compared with those which have been superseded. Therefore, speed may reach many times the rate now attained, the size of vehicles may be greatly increased and the cost of carriage for the longest distances reduced to an astonishing minimum; so that as progress goes on in developing the means and methods of distribution, the habits and needs of men will be more and more modified, with consequences to social order and the general conditions of life

which may be far greater than have yet been imagined.

But this is not all. Another fact is still more wonderful. Coincident with this sudden transfer from animal power to steam have come the new and amazing means of transmitting intelligence. In a brief generation the barriers of time and distance, hitherto so formidable, have been swept away by telegraph and telephone. No longer limited to the agencies by which material things are transported, we send our thought and speech with lightning swiftness to the four quarters of the globe, and hold all lands and peoples within the sphere of instant intercourse. So recent is this miracle that we are still dazzled by its marvels without realizing its tremendous import.

That this substitution of steam and electricity as the instruments of commerce and communication has been an immeasurable gain is witnessed here and everywhere by half a century of unparalleled progress. Along these wondrous pathways the world has literally leaped. Released from dependence on beasts of burden, the entire realm of industry has been quickened and enlarged; productive energy has been vivified by new and limitless means of distribution; the products of the whole earth are embraced in wide circles of exchange; all the luxuries of all lands are brought to every household; wealth has multiplied until we are almost surfeited with its abundance, when other people possess it; the genius of invention has been stimulated to larger exercise, the sphere of thought grandly extended, the impulses of charity awakened to nobler activity, while keener sympathy through closer contact is pointing the road to real brotherhood.

But these manifold benefits have not been secured without many and serious evils. The potent energy which produced such prodigies of utility and convenience has

generated an array of forces which already test with severe strain the structure of modern society. So radical a change in the methods of distribution, and consequently of production, was sure to be attended with peril as well as beneficence, and to entail a series of results, immense and far-reaching. Passing by those acute abuses which are incident to the process of development, which are transitory and must gradually disappear, we may well consider the more profound and permanent effects, what I venture to call the economic effects, of present and future methods of transportation and intercourse upon the whole range of social activity. This brings into view again the impressive fact mentioned at the outset, and suggests some graver consequences than those that appear on the surface and appeal to ordinary observation.

When movement was measured by the strength and endurance of animals, only a limited area could be reached from a common center. Its slowness and expense confined all inland distribution within narrow bounds. Only eighty years ago it took a week to send a letter, and cost \$125 to move a ton of freight, from Philadelphia to Pittsburg; and the average price for carrying the necessities of life was not less than twenty cents a ton for each mile of distance. On such a basis most commodities were shut off from distant markets, and farm products, for example, would seldom permit of conveyance more than 100 or at most 150 miles. Only such articles as were of small bulk and weight compared with their value were moved to any considerable distance from the place of production. For this reason the requirements of an ordinary family were almost wholly supplied from near-by sources. And this means—without amplifying the statement—that productive energy, for the most part, was restricted by the consuming capacity of the surrounding neighborhood.

The forces outside each little circle were but feebly felt and had slight influence upon its separate affairs. Broadly speaking, the business of each locality was adjusted to its own conditions and was practically undisturbed by like operations in other places. What we call competition was held in check by slow and costly means of conveyance; its effects were moderate and limited, its friction seldom severe.

But the use of steam for motive power and electricity for sending news increased enormously the range of accessible markets, and at once intensified competition by the celerity and cheapness of distribution. Industrial strife has already become world-wide in extent and distance an ineffectual barrier against its destructive assaults. For distance as a commercial factor is not at all a matter of miles, it is merely a question of time and money. So the effect of cheap conveyance and quick communication is to bring remote places closer together. For all the practical needs or enjoyments of life Manila is nearer New York now than Montreal was a century ago; and the whole world could be easier governed from Washington to-day than could the United States when the capital was located on the Potomac.

Our grandparents got their supplies mainly in the neighborhood where they resided, and only a few persons were concerned in their production. To-day it may safely be said that five millions of people and five hundred millions of capital are directly or indirectly employed in furnishing a family dinner. When merchandise of every description is moved by the ton at great speed from one end of the land to the other, and at an average cost of less than three quarters of a cent a mile, as is now the case, the expense of transport is but a trifling impediment to the widest distribution.

Nor should we forget that it was the

opening up of new and ever enlarging markets, by the cheapness of steam transportation, which gave the first opportunity for the extensive use of machinery; and this in turn quadrupled the capacity of labor and greatly reduced the cost of large scale production. By this revolution in the methods of manufacture—caused by the railroad and steamship—the mechanic was supplanted by the operative, and the skilled and independent craftsman of former days found his occupation gone. For what chance now have hand-made articles when the factory-made product is carried across the continent at nominal cost? But the factory without the railroad would be only a toy shop. If its wares had to be hauled over country roads by mules and horses, the points they could reach would be few and near by, and thus contracted sales would limit the size of the plant and the volume of its business. It is simply because transportation is now so speedy, so cheap and so abundant that great establishments have become profitable and driven their smaller rivals from the field.

These facts—which might be multiplied without limit—bear directly, as I think, and with a force not fully perceived, upon the whole problem of industrial competition. The argument runs this way: As the means by which industrial products are distributed become more convenient, quicker in action and less expensive, the area of distribution rapidly enlarges, and as the area of distribution enlarges the competition of industrial forces increases in something like geometrical ratio. The movement of property by rail in the United States alone already exceeds four millions of tons every twenty-four hours. Think of the rivalry of products, the strife of labor, the strain and struggle of trade, which such a movement implies. With the constant acceleration of that movement, which is certain to happen, how long can the fric-

tion be endured? How soon will it become unbearable?

The truth is that new conditions have arisen and new methods must be adopted. All the pressure of modern life impels to the coordination of effort. We see that discord and antagonism, to say nothing of their moral bearing, have far less efficiency than harmony and cooperation. The world is searching for economies. It is intolerant of needless expense. The way a thing can be done the easiest and cheapest is the way it is bound to be done and the way it ought to be done. We want the best results and find that they come from combination. The old aphorism, 'in union there is strength,' takes on a new meaning. It is the law of growth and increase. It applies to industries as well as to individuals. To unite is to advance. The concentration of process is the expansion of output.

Thus the potent agencies by which distribution is now so rapidly and cheaply effected, which so combine and intensify the forces of production, are fast altering the conditions and changing the character of industrial development. And the end is not yet; it outruns imagination. What will be the ultimate effect of these methods of conveyance and intercourse when brought to higher perfection and employed with still greater efficiency? When these agencies of commerce are increased in number and capacity, as they will be; when cost is still further and greatly reduced, as it will be; when speed is doubled, as it will be, and quadrupled, as it may be; when the whole United States shall have reached the density of population now existing in Great Britain—how can industrial competition possibly survive?

When Adam Smith wrote 'The Wealth of Nations,' it took two weeks to haul a wagon-load of goods from London to Edinburgh, and such a thing as a business or industrial corporation was virtually un-

known. To-day the great enterprises of the world are in the hands of corporations, and the time is fast approaching when they will absorb all important undertakings. Why? Simply because the railroad and the steamship—cheap and rapid transportation, all the while growing cheaper and quicker—ever widening the area of profitable distribution, furnish the opportunity, otherwise lacking, for the employment of larger and still larger capital. This opportunity permits and encourages the concentration of financial resources; so that, within limits not yet ascertained, the larger the business the greater its possibilities of gain. But the legitimate, the inevitable offspring of corporations is monopoly. Why? Simply because the operation of these massive forces—reaching and opposing in every market of the world—begets an extremity of mutual danger which always invites and often compels a common agreement as to prices and productions; that is, a trust. Just as the implements of warfare may become so devastating in their effects that nations will be forced to live in amity, so the destructiveness and exhaustion of commercial strife in these larger spheres of action will make combination a necessity.

So, in the measureless and transforming effects of modern transportation, and the ends to which it resistlessly tends, I find the primary cause of the economic revolution upon which we have entered. The incoming of these new and unfettered forces not only changed the basic function of society, but greatly disturbed its industrial order. In the effort to restore a working equilibrium strange questions arise and novel difficulties are encountered. Already we are compelled to doubt the infallibility of many inherited precepts and to reopen many controversies which our grandsires regarded as finally settled. The ponderous engine that moves twice a thousand tons

across an empire of states, the ocean steamer that carries the population of a village on its decks and the products of a township in its hold, the vast mergers of producing and distributing machinery whose colossal grasp covers land and sea, are indeed splendid evidences of constructive genius and financial daring, but more than this, they are economic and social problems whose complexity bewilders and whose magnitude dismays. They force us to discredit the venerable maxim that 'competition is the life of trade,' and warn us I think, that the political economy of the future must be built on a nobler hypothesis. If it be true in the long run, as I believe experience teaches, that where combination is possible competition is impossible, is it not equally true that combination becomes possible just in proportion as transportation becomes ampler, speedier and cheaper? So the opportunity, if not the necessity, for combination has already come in many lines of activity and will certainly come in many more. For the circumstances that permit competition, its *sine qua non*, is mainly difference of conditions. Practically speaking, this difference is chiefly found in the means of distribution. As that difference disappears, with the constantly diminishing time and cost of transport, the ability to combine will increase and the inducement to do so become overwhelming. That seems to me the obvious tendency of industrial and social movements to-day, and that tendency, I predict, will be more and more marked as time goes on.

How fast the process will develop, or what phases it will assume, does not yet admit of confident forecast. Many experiments will be tried, many failures occur, before the readjustment is accomplished. Remedies will be sought in profit-sharing, in the distribution of corporate stocks among employees, in the socialization of public utilities, in largely increasing the

functions of government. By whatsoever road reached the ultimate if not early outcome will probably be some form of centralized control with diffused or decentralized ownership. Meanwhile, the exactions of monopoly, the feebleness of legal restraints, the heaping up of fabulous fortunes, the prejudice of the ignorant, the envy of the incapable; and through all and over all the inappeasable voice of labor demanding, not without reason, a larger share of the wealth which it produces.

That these great consolidations are wholly desirable I certainly do not pretend. On the contrary, they occasion much cause for regret and not a little for grave apprehension. The utilization of new forces, the transfer to new methods, the control of producing and distributing agencies by huge combinations, must in the nature of the case inflict many hardships and involve many surrenders. But a great principle underlies this movement, the principle of industrial peace and efficiency, the principle of cooperation. Beside all question that principle is to govern, despite all drawbacks its operation will be beneficent.

So, in the unrest and discontent around us, deep-seated and alarming here and there, I read the desperate attempt to avoid the effects of industrial competition and a tremendous protest against its savage reprisals. Every trust and combination, whether organized by capitalists or by artisans, every strike and lockout, is a repudiation of its teachings and a denial of its pretensions. The competitive theory may have answered the age of mules and sailboats and spinning-wheels, but it fails to satisfy the interlacing needs, or to sustain the interdependent activities, which are founded on modern methods of intercourse and distribution; it is a theory unsuited to the era of railways and wireless telegraphy, this era of ours, so restless in thought, so resistless in action.

I much mistake, therefore, if we are not entering upon a period of great transitions, a period of difficulty and many dangers. The whole structure of industry and social life is liable to be subjected to a strain—possibly to a shock—for which experience furnishes no guiding precedent. We have settled the administrative questions; we can collect taxes, build court-houses and pay the policeman. We have settled the political questions; the nation lives and will live, the greatest and grandest in all the earth. But the further test is now to come, the test of the ocean liner and the limited express. Can we settle the economic questions? Can we raise this wide realm of industry from selfishness to charity, from strife to friendship, from competition to cooperation, from the warring instincts of the savage state to the larger and nobler needs of associated life? This is the problem of railroad and steamship, of telegraph and telephone, of the subtle and limitless forces of modern life, the problem which will test the wisdom of statesmanship and tax the resources of public authority.

MARTIN A. KNAPP.

SCIENTIFIC BOOKS.

A Systematic Handbook of Volumetric Analysis. By FRANCIS SUTTON, F.I.C., F.C.S., etc. Ninth Edition, revised and enlarged. Philadelphia, P. Blakiston, Son & Co.

Sutton's 'Analysis' is so well known that the highest praise that can be paid this book is the statement that it is even better than the eighth edition. But few new chapters have been added, the most important being on magnesium and the azo-dyes. The individual chapters have been but little changed. Few new methods have been added and fewer obsolete processes dropped. Conservatism is undoubtedly necessary in a work of this kind, but it may be carried too far. The book would be more valuable if the author with his large experience were more ready to discard